RESEARCH HIGHLIGHT

February 2013

Socio-economic Series 13-002

Comparing Canadian New Urbanist and Conventional Suburban Neighbourhoods (Updated)

BACKGROUND

New urbanism is an urban design movement that emerged in the 1980s as an alternative to the typical post-war suburb. The originators of the concept[1] borrowed design standards from the pre-automobile age aiming to create neighbourhoods with connected and pedestrian-friendly streets, mixed housing types, local commercial services and a higher level of aesthetic and public amenities.

New urbanist design principles are most clearly stated in the 1996 Charter of the New Urbanism. The design elements are intended to influence behaviours, such as travel decisions and attitudes of residents: mixed uses will accommodate "many activities of daily living within walking distance;" mixed housing will "strengthen the personal and civic bonds essential to an authentic community;" better streetscapes and pedestrian networks will "encourage walking and enable neighbours to know each other;" and public amenities will "reinforce community identity."

The literature review revealed several studies comparing behaviours of occupants of new urbanist and older neighbourhoods to conventional suburban ones. The studies tended to focus on single issues, such as travel behaviour, and are based chiefly on American examples. The review identified a clear research gap with regard to Canadian developments and examination of the full range of travel and social behaviours.

This study examines data from Canadian examples of new urbanist development compared to corresponding examples of conventional suburban development to test the hypothesis that new urbanist design features are associated with more sustainable travel behaviour and a higher degree of resident engagement with one another and with their communities.

PURPOSE OF THIS REPORT

The purpose of the study is to gather data from selected new urbanist developments (NUDs) and conventional suburban developments (CSDs) in order to determine whether the NUDs achieved the following objectives to a greater degree than the CSDs.

Design characteristics

- Better access to daily destinations, such as public open space, institutional and commercial/retail destinations
- More pedestrian routes and connectivity
- More housing choice
- Less land per housing unit

[1] American architects Andrés Duany and Elizabeth Plater-Zyberk first developed the concept that was later adopted by the Congress for the New Urbanism, founded in 1993.

Canada

CMHC SCHL
HOME TO CANADIANS

Behaviour and attitudes

- Less car use for weekday urban travel
- More walking and bike use for daily destinations
- Greater use of public transit
- Higher resident satisfaction with neighbourhood design
- More use of public open/green space
- More social interaction with neighbours
- Greater sense of neighbourhood attachment

The study also employs statistical procedures to examine the relationships between the built-form design features and the travel behaviour observed among these different neighbourhood types.

STUDY METHODOLOGY

This study addresses the research questions empirically, by conducting a cross-sectional comparison between four new urbanist developments and four conventional suburban developments in Canada. This was carried out in the following steps:

Literature review: The study began with a review of the literature on the post-occupancy impacts of new urbanist design features. The review covered both the U.S. and Canada and was focused on travel behaviour and social attitudes that may be affected by neighbourhood design features such as density, mix of uses, street patterns and quality of the streetscape.

Scan for NUDs: A scan was conducted in order to identify the most suitable NUDs for inclusion in the study. Besides searching on the Internet and in newspaper archives, key informants in different regions of the country were contacted for leads on promising NUDs. The scan resulted in the identification of 38 distinct projects that had new urbanist features.

Selection of NUDs: Once a potential NUD was identified, contact was made with a local planner in order to gather more detailed information about the development, including its age, size, number of residential units and non-residential land uses. Based on this information, a final selection of four NUDs was made.

Selection of comparable CSDs: Four conventionally designed neighbourhoods were then chosen that would allow for meaningful comparison with the selected NUDs. For each NUD, a nearby CSD was chosen that had a similar location within the urban context, demographics, price ranges, size and age of neighbourhood, as well as similar levels of access to public transit.

Collection of neighbourhood design data: Geographic Information System and satellite sources along with on-site surveys and data from local planners provided detailed information on the physical design characteristics of each neighbourhood. Neighbourhood metrics included the area, number of housing units, non-residential land uses, street widths, setbacks, and so on.

Geocoding of neighbourhood metrics: Much of the data collected on the physical design of the neighbourhood was geocoded for spatial presentation and tabulation.

Household survey: A quantitative survey was conducted among the eight study neighbourhoods in order to assess travel and social behaviours. The questionnaire included a 24-hour trip diary for all household members. The survey was carried out largely through an online questionnaire but was also available in print form or could be filled out with telephone assistance. The survey period was from August 30 to October 30, 2006. A total of 2,043 households completed and returned the survey.

Geocoding of survey results: All spatial elements (home and daily destinations) of the survey responses were geocoded for detailed analysis of travel distances.

Analysis of survey results: The various data sets were analyzed to quantify differences between NUD and CSD neighbourhoods.

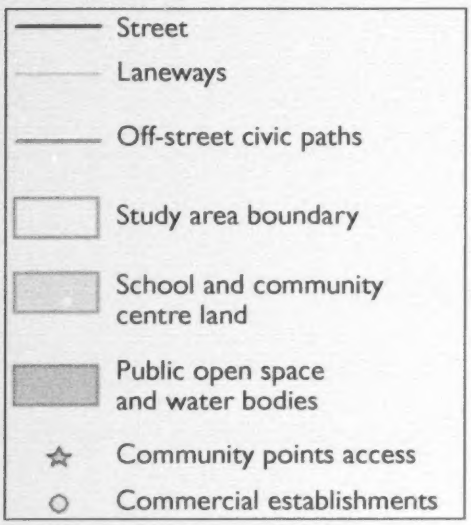
Statistical analysis: Selected results were included in a correlation analysis that explored linkages among urban design variables and travel behaviour. A regression analysis was carried out in order to assess the main factors affecting vehicle use in the eight study neighbourhoods.

THE STUDY NEIGHBOURHOODS

The four NUDs and their CSD counterparts selected for inclusion in the study are shown in table 1.

Table 1 Neighbourhoods selected for inclusion in the study

New Urbanist Developments	Conventional Suburban Developments	City	Urban Context
McKenzie Towne	McKenzie Lake	Calgary	Outer suburbs
Garrison Woods	North Signal Hill	Calgary	Inner suburbs
Cornell	Woodbine North	Markham	Outer suburbs
Bois-Franc	Nouveau Saint-Laurent	Montréal	Inner suburbs



Legend for neighbourhood plans (plans based on construction completed at the time of this study's survey)

MAJOR FINDINGS

Physical design metrics

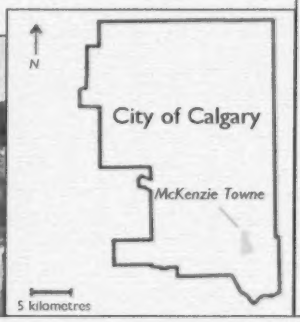
A key characteristic of urban form is housing density. In general, gross residential densities in the NUDs averaged 2,021 dwellings per km^2 (20.2 uph), against 1,163 dwellings per km^2 (11.6 uph) in the CSDs, which indicates that the NUDs were significantly more compact. The NUDs also had a greater mix of housing types; the NUDs had less than half the proportion of single-detached units found in the CSDs and five times the percentage of multi-family units in buildings higher than five storeys.

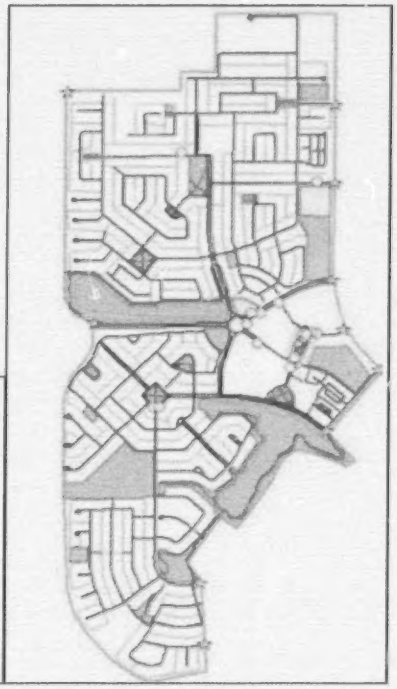
In our study neighbourhoods, we observed almost double the number of stores and services, as well as educational and recreation/entertainment establishments, within 1 km of the neighbourhood centroid in the NUDs than in the CSDs. However, when looking at employment within a 5-km radius of the neighbourhood centroid, we found that the NUDs had 17 per cent fewer jobs than did the CSDs. Again, each CSD was selected to have a location similar to its NUD counterpart with regard to distance to the metropolitan core.

In the four NUDs, we observed slightly more public open and green space than in the CSDs (14.4 per cent of total surface area, versus 13.8 per cent). The street density was about the same in the two types of neighbourhoods but, when lanes were added to the metric, NUDs showed a street density 38 per cent higher than did CSDs. As for off-street civic paths (excluding sidewalks), the NUDs had a higher density than the CSDs (2.3 km versus 1.9 km length/total km^2). Together, the path/street/lane density in the NUDs was 36 per cent higher, on average, than in the CSDs.

McKenzie Towne

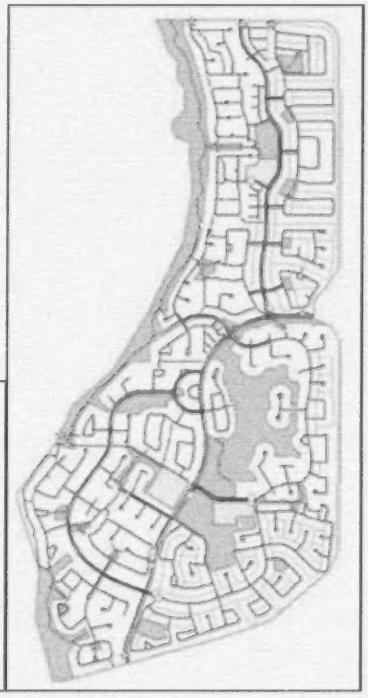
- 20 km from Calgary's central business district (CBD)
- Study area is 2.6 km², developed as of 2006: 4,625 homes in study area out of 8,000 at build-out
- 60% single-detached housing, with townhouses, duplexes and apartments; gross density of 17.2 units per hectare (uph)
- Commercial centre on site
- 16% of site is public open space
- 2 schools within 1 km of centre
- 83% of streets have sidewalks on both sides





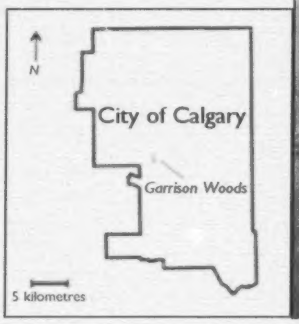
McKenzie Lake

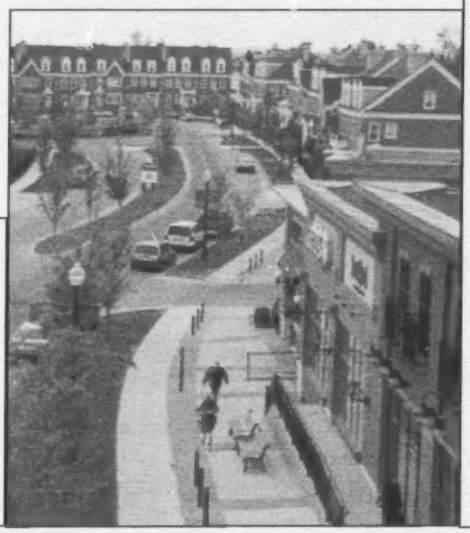
- 20 km from Calgary's CBD
- Study area is 4.2 km², completed by 1999: 4,641 homes
- 90% single-detached housing, with townhouses, duplexes and apartments; gross density of 10.5 uph
- Few commercial uses, 4 schools within 1 km
- 19% of site is public open space
- 40% of streets have sidewalks on both sides

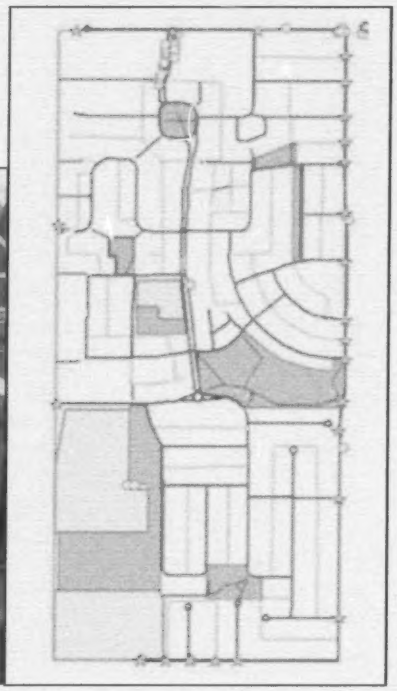


Garrison Woods

- 5 km from Calgary's CBD
- Study area is 0.77 km², completed in 2005: 1,535 homes
- Over 30% apartments, 20% townhouses and 15% duplexes; gross density of 20 uph
- 12% is public open space (high quality), the most paths/km²
- The most non-residential uses within 1 km, 11 schools within 1 km
- 53% of streets have sidewalks on both sides

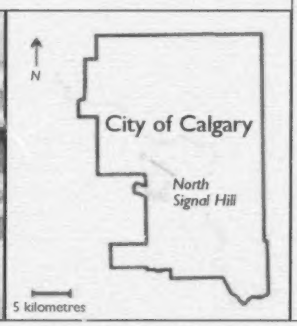


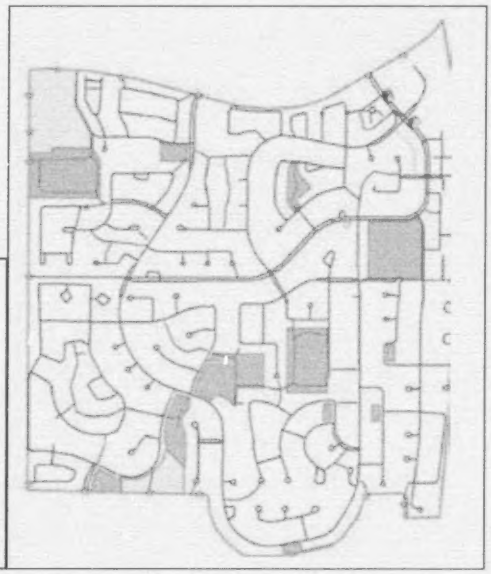




North Signal Hill

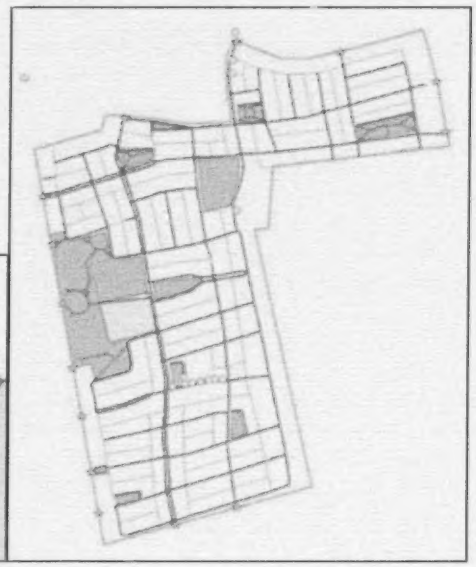
- 8 km from Calgary's CBD
- Study area is 2.5 km², completed in the 1990s: 3,114 homes
- 70% single-detached housing; gross density of 12.6 uph
- The fewest commercial uses, 1 school within 1 km
- 8% is public open space
- 33% of streets have sidewalks on both sides





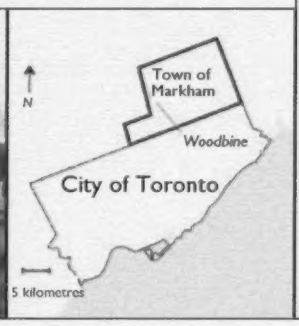
Cornell, Markham

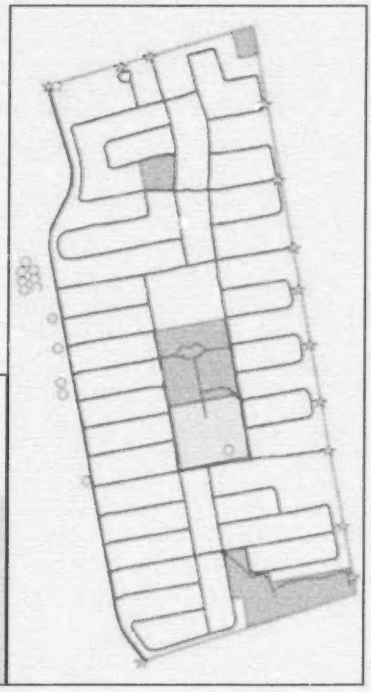
- 30 km from Toronto's CBD
- Study area is 1 km^2, began construction in 1999
- 1,894 homes in study area, 10,000 at build-out
- 36% single-detached housing, 46% townhouses, 17% semi-detached homes and 1% apartment; gross density of 19.6 uph
- Some commercial uses: main street
- 13% is public open space
- 1 school within 1 km
- 93% of streets have sidewalks on both sides



Woodbine North, Markham

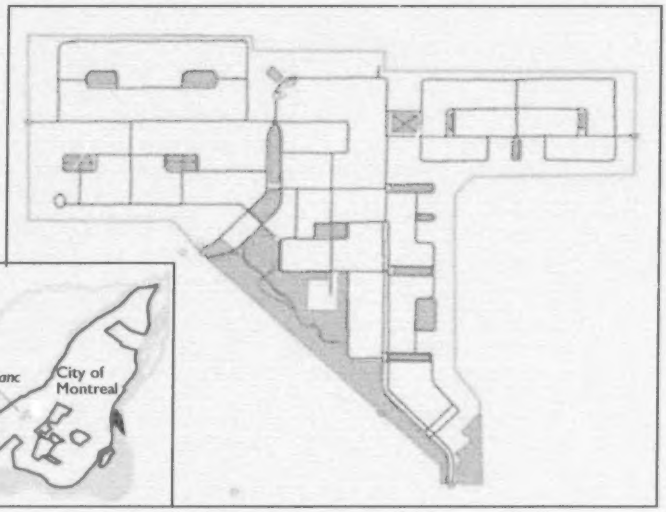
- 28 km from Toronto's CBD
- Study area is 0.75 km^2, completed in 2002: 1,218 homes
- 64% single-detached housing, 15% townhouses and 21% semi-detached homes; gross density of 16.3 uph
- Adjacent to shopping centre, 1 school within 1 km
- 10% is public open space
- 19% of streets have sidewalks on both sides

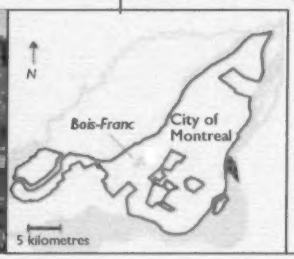




Bois-Franc

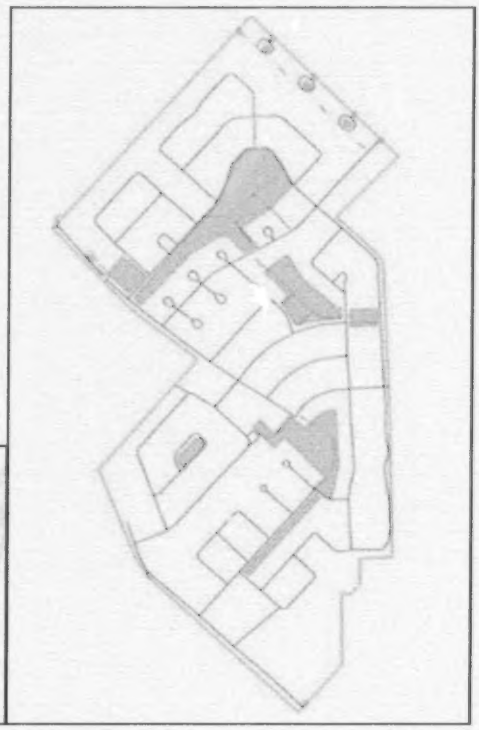
- 11 km from Montréal's CBD
- Study area is 0.9 km^2, began construction 1993: 2,605 homes at the time of study, 5,300 at build-out
- 43% townhouses, 50% multi-family homes, 7% semi- and single-detached homes; gross density of 30.7 uph
- Small commercial centre
- 13% is public open space (high quality)
- 4 schools within 1 km
- 81% of streets have sidewalks on both sides

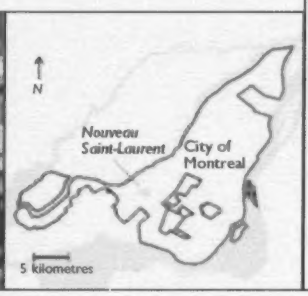




Nouveau Saint-Laurent

- 11 km from Montréal's CBD
- Study area is 0.9 km^2, with 970 homes in study area, 1,200 at build-out
- 52% single-detached housing, 24% townhouses, 4% semi-detached homes and 20% multiplex dwellings; gross density of 10.5 uph
- Very few commercial uses, no school within 1 km
- 10% is public open space
- 21% of streets have sidewalks on both sides





We found a very high percentage of streets without sidewalks in the CSDs compared to the NUDs (27.5 per cent of street km in CSDs, versus 2.8 per cent in NUDs). Over three quarters of the streets in the NUDs had sidewalks on both sides of the street, compared to only 28.5 per cent in the CSDs. Similarly, the NUDs had significantly smaller setbacks when compared with those observed in the CSDs; 83.7 per cent of streets in the CSDs had setbacks larger than 5.5 metres, compared to only 43.1 per cent of streets in the NUDs. In terms of street widths, on average, the NUDs had about three times more streets that were narrow, at less than 7.6 metres wide, than the CSDs (11.5 per cent, versus 3.9 per cent).

We found that the NUDs offered somewhat better pedestrian connectivity than the CSDs. When we computed the average ratio of the straight-line to network distances between each home and all other homes within each neighbourhood, we found that the NUDs had slightly higher connectivity values (0.78) for the ratio when compared with the CSDs (0.74), for a difference of about 5 per cent.

Some of the physical design metrics are summarized in table 2.

Household survey findings

The findings presented in this section were obtained from the over 2,000 households who completed the survey described above.

Household profiles

The survey revealed that responding households living in the CSDs had more household members (3.3) than those living in the NUDs (2.7). We also observed that households residing in the CSDs were more likely to include children than their counterparts in the NUDs. Not surprisingly then, we observed a significantly larger percentage of students in the CSDs than in the NUDs.

When we focus on adults from the responding households, we observed that adults in the NUDs were younger than their counterparts in the CSDs. We found that older cohorts over the age of 45 constituted 36 per cent of the residents in the CSDs but only 28 per cent in the NUDs. Furthermore, a higher percentage of NUD dwellers were employed than their counterparts in the CSDs. This suggests that the NUDs attracted younger adults, whereas the CSDs attracted older adults with children. Consistent with this interpretation, we found that household incomes were about 8 per cent higher in the CSDs than in the NUDs. The average household income in both types of developments was in excess of $100,000.

As one would expect from the difference in household size between the two types of neighbourhoods, the housing units of responding households in the CSDs were larger in size than those found in the NUDs. For instance, 80 per cent of the housing units in the NUDs had three bedrooms or less, compared with 45 per cent in the CSDs. And since the housing stock in the NUDs was smaller in size, the homes were, on average, cheaper than the homes in the CSDs.

Table 2 Summary of certain physical design metrics

Neighbourhood	Total Area (km^2)	% Single-Detached Houses	Gross Density (uph)	Non-Res. Land Uses Within 1 km*	% Public Green/ Open Space	% Sidewalks Both Sides	% Set-backs >5.5 m	% Streets < 7.6 m Wide	Ped. Connect-ivity	Street/ Lane/Path Density
Bois-Franc	0.85	3	30.7	24	12.7	80.7	35.5	24.8	0.76	15.7
Nouv. St-Laurent	0.92	52	10.5	12	9.6	21.2	97.1	1.5	0.71	15.3
Cornell	0.97	36	19.6	22	12.8	93.1	32.4	2.1	0.82	25.9
Woodbine North	0.75	64	16.3	46	8.9	19.4	76.5	0	0.80	18.7
Garrison Woods	0.77	28	19.9	132	12.2	52.8	73.8	4.9	0.79	23.8
North Signal Hill	2.46	72	12.6	49	8.2	33.1	82.5	10.4	0.70	15.4
McKenzie Towne	2.69	59	17.2	45	16.2	83.2	31.0	13.9	0.74	21.8
McKenzie Lake	4.42	91	10.5	16	18.6	40.2	78.8	3.5	0.76	16.8
NUD avg.	**1.32**	**31**	**20.2**	**55.8**	**14.4**	**77.4**	**43.1**	**11.5**	**0.78**	**21.8**
CSD avg.	**2.14**	**70**	**11.6**	**30.8**	**13.8**	**28.5**	**83.7**	**3.9**	**0.74**	**16.0**

* includes commercial and institutional land uses

Almost 38 per cent of the housing units of the responding households in the CSDs were under $450,000, compared to 68 per cent in the NUDs.

There were no significant differences in housing tenure between the two types of developments. In both the NUDs and CSDs, 96 per cent of responding households owned their dwellings.

Perceptions of the neighbourhood

The survey revealed that, in comparison with their CSD counterparts, nearly double (60 per cent, versus 34 per cent) the respondents in the NUDs reported being very satisfied with the physical design of the streets, landscaping and façades in their neighbourhoods. Similarly, double the respondents in the NUDs found the streetscapes very pleasant for walking, compared to the households in the CSDs (85 per cent, versus 44 per cent). Similarly, the design of the streetscapes was considered to be very safe for walking and biking by 51 per cent more respondents living in NUDs than those residing in CSDs (55 per cent, versus 37 per cent). These perceptions may help to explain the other survey results that suggested that 70 per cent of households in NUDs, compared with just 47 per cent of households in CSDs, found it very convenient to either walk or bike to parks.

Furthermore, 52 per cent of NUD respondents reported visiting public open or green spaces several times a week, compared to only 40 per cent of the respondents in the CSDs, even though our neighbourhood metrics showed that NUDs had only slightly more public green and open space than the CSDs and that the CSDs had more children per household.

Table 3 Summary of certain survey results: Household profiles

Household Variable	NUD Avg.	CSD Avg.
Household size (# persons)	2.7	3.3
Household members over 9 yrs. (# persons)	2.2	2.7
Household income ($)	110,000	119,000
House price ($)	411,000	495,000
House size (# bedrooms)	2.9	3.6

There also appears to be a difference between the two types of developments in terms of respondents' appreciation of the architectural quality of their respective neighbourhoods. A large percentage (29 per cent) of respondents from NUDs cited the architectural quality of homes and other buildings in the neighbourhood as the number one factor in choosing the neighbourhood. In comparison, only 6 per cent of respondents from the CSDs cited this as the primary reason to locate in the neighbourhood. The quality of their own dwelling unit was cited by 22 per cent of respondents from the CSDs as the primary reason to locate in that particular neighbourhood, compared to only 13 per cent of respondents from the NUDs.

Respondents from NUDs reported being more attached to their neighbourhoods compared to their CSD counterparts (50 per cent, versus 36 per cent were very attached), despite the fact that NUD respondents had, on average, lived in the neighbourhoods for shorter periods of time (reflecting the relatively recent construction of these neighbourhoods).

Social interaction

We observed that the NUD respondents greeted their neighbours more often than respondents living in the CSDs, with 35 per cent reporting a greeting almost every time they were out for a walk, compared to 27 per cent for CSD households. NUD households also reported socializing face-to-face with their neighbours more often, with 40 per cent saying they did so several times a week, in contrast to the CSD households, 34 per cent of whom reported doing so.

Table 4 Summary of certain survey results: Perceptions of neighbourhood design

Perception of Neighbourhood Design (% of Total Respondents)	NUD Avg.	CSD Avg.
Streetscapes very pleasant for walking	85	44
Streets very safe for walking, biking	55	37
Very convenient to walk, bike to open space	70	47
Very attached to neighbourhood	50	36
Very satisfied with overall design of neighbourhood	60	34
Visit public open space several times a week	52	40
Architectural quality of the neighbourhood primary factor to locate there	29	6

Although CSD respondents were more likely to hold a membership in sports or social groups, households in NUDs attended more community events per year, on average, than their CSD counterparts.

These results are consistent with our finding that respondents from NUDs tended to walk and bike more than their counterparts in the CSDs, which might have facilitated their social interaction with neighbours. We also observed that the spatial extents of social interactions were slightly different between the two types of neighbourhoods, with respondents of CSDs tending to socialize more with immediate neighbours, while those who lived in NUDs tended to extend their networks to the entire neighbourhood.

General household travel behaviour

We found significant evidence to support the assumption that responding households in the NUDs walk and bike more than their CSD counterparts. Fully 51 per cent of NUD households reported walking and biking to local services and stores several times a week, compared to only 19 per cent for CSD households. Also, 64 per cent of NUD respondents said they stroll or bike for leisure several times a week in the warm months, compared to 52 per cent of CSD respondents. These findings are consistent with the earlier finding concerning resident perceptions of their environments: responding households found NUDs to be more pleasant and safer environments for walking and biking.

To test how changes in built form can affect household travel behaviour, we asked respondents about their travel behaviour in their previous home locations. We found that, since their move to the NUD, 37 per cent of these households reported they were walking a lot more than they did in the previous locations. In contrast, only 20 per cent of households in CSDs reported a lot more walking in their new location. In fact, a significantly larger percentage (26 per cent) of respondents reported a decline in their walking since their relocation to a CSD than those who relocated to a NUD (11 per cent). Since their relocation to the NUD, 39 per cent of respondents in NUDs reported a decline in their car use. Only 18 per cent of households in CSDs reported a decline in their driving since their move, while 47 per cent reported an increase in car use, compared to only 29 per cent of NUD respondents. These findings support the contention that the design characteristics of NUDs encourage higher walking and biking modal shares.[2]

Table 5 Summary of certain survey results: Social interaction

Social Interaction (% of Total Respondents)	NUD Avg.	CSD Avg.
Greet neighbours while out, almost every time	35	27
Socialize face-to-face with neighbours several times a week	40	34
10+ neighbours known by name	52	51
Member of neighbourhood club/group	32	41
Participate in community events, 4+/year	15	11

The survey also revealed that responding households in the NUDs were 24 per cent less likely to own more than one car than their CSD counterparts: only 61 per cent of NUD households owned two or more cars, while 80 per cent of CSD households did. Those moving to a NUD had similar rates of car ownership as in their last location. For example, 59 per cent of NUD respondants had two or more cars in both locations. However, those who had moved to CSDs showed increased rates of car ownership compared to their previous location, going from 70 per cent to 80 per cent of households having two or more cars.

A key characteristic of the built environment that influences travel behaviour is the availability of parking spaces. The greater availability of parking spaces is thought to promote higher levels of automobile ownership. Our results indicate that NUD respondents reported significantly lower parking capacity than their CSD counterparts. In general, 62 per cent of households in the CSDs reported having three or more parking spaces, compared with only 35 per cent of households in NUDs. Thus, households in NUDs tended to have lower parking access, own fewer cars and drive less than those in the CSDs.

24-hour travel diary analysis

The mode split analysis suggests that NUD respondents had a lower auto mode share (as a driver or passenger) than their CSD counterparts (78 per cent, versus 85 per cent). Walking mode share was significantly higher for NUDs than for CSDs (11 per cent, versus 5 per cent), especially

[2] As described later, further research in this area would enhance understanding of the influence of any self-selection bias.

for shopping trips (9 per cent, versus 2 per cent). As far as public transit is concerned, the NUD and CSD respondents reported the same transit mode share (both 9 per cent). This may reflect the fact that CSD counterpart communities were selected in part on the basis of their similarity to NUDs in terms of transit service and location.

In terms of trip purpose, the NUD respondents reported a higher share of trips for walking or biking for pleasure than their CSD counterparts (3 per cent, versus 1 per cent). Over 50 per cent more NUD households reported walking trips than did their CSD counterparts (21.3 per cent, versus 14 per cent). However, among those households reporting trips, the walking trips per household were not very different between the two types of neighbourhoods (2.3 for NUD respondents, versus 2.0 for the CSD respondents).

The analysis of the 24-hour vehicle kilometres travelled (VKTs) reported by each responding household indicates that the CSD respondents had a 24-per-cent higher level of VKTs per household than their NUD counterparts (46.0 km, versus 37.1 km).

Table 6 Summary of certain survey results: Travel behaviour

Travel Behaviour	NUD Avg.	CSD Avg.
Walk, bike to local services and stores, several times a week (% of total respondents)	51	19
Stroll, bike for leisure, several times a week (% of total respondents)	64	52
Walk a lot more than in previous location (% of total respondents)	37	20
Drive less than in previous location (% of total respondents)	39	18
Own two or more cars (% of total respondents)	61	80
Vehicle kilometres travelled (VKTs) per household	37.1	46.0
Households reporting walk trips (% of total respondents)	21.3	14.0
% trips by walking	11	5
% trips by automobile (as driver or passenger)	78	85
% trips by public transit	9	9

STATISTICAL ANALYSIS

In this section, we provide a statistical analysis of the results presented above. This analysis permits us to explore relationships among some of the variables presented above and help answer key research questions. The main question addressed in this section is "Are the differences in urban form linked to differences in travel behaviour in the study neighbourhoods?" We address this question by first conducting a series of one-to-one correlations between built-form variables and travel behaviour, as measured by our household survey, to identify significant relationships. We then proceed with a multivariate regression analysis of VKTs in order to examine the influences on VKTs and control for extraneous variables, such as household size and income.

The correlations are carried out using variables for which data was available at the household level and those for which data was aggregated to the neighbourhood level. Table 7 shows the results of one-to-one correlations using neighbourhood-level, built-form variables against travel behaviour variables captured or estimated at both the household and neighbourhood levels. The travel behaviour variables include survey responses to questions such as how frequently respondents walk or bike to neighbourhood destinations; how frequently they walk or bike in the neighbourhood with no destination; whether they walk more now than in their previous location; whether they drive less now than before; the number of walking trips reported by the household; and the number of household VKTs. These travel behaviour variables were all measured at the household level. Other travel behaviour variables were measured at the neighbourhood level, including average VKTs per household for each neighbourhood; percentage of neighbourhood households reporting walking trips; and neighbourhood average walking mode share.

Table 8 shows the results of one-to-one correlations using household-level, built-form variables and travel outcome variables captured at both the household and neighbourhood levels. The built-form variables include items that can be measured at the block or household level, such as whether there are sidewalks on the street where the house is located; the average setback on that street; the width of the street; and the pedestrian connectivity of a household at that particular location. The built-form variables also include responses to selected questions from the household survey,

Table 7 Correlations using neighbourhood-level, built-form variables against travel behaviour

Neighbourhood-Level Built-Form Variables	Household-Level Travel Behaviour Variables						Neighbourhood-Level Travel Behaviour Variables		
	Walk or Bike to N'hood Destin-ations	Walk or Bike in the N'hood With no Destination	Walk More Now than Before	Drive Less Now than Before	Number of Walking Trips	VKTs	Avg. VKTs per H'hold	% of H'holds Reporting Walking Trips	Avg. Walking Mode Share
Dwelling density	+	+	+	+	NS	-	-	-	+
Housing mix	+	+	+	+	+	-	-	-	+
Employment within 5 km	NS	+	NS	NS	-	-	-	-	-
Non-residential land uses within 1 km	+	-	-	NS	NS	-	-	-	NS
Pedestrian connectivity	+	+	+	NS	+	+	+	-	+
Street/lane density	+	NS	+	+	+	+	+	NS	+
% of site that is public open space	+	NS	+	NS	NS	+	+	+	-

+ = positive correlation significant at the 95% confidence level
- = negative correlation significant at the 95% confidence level
NS = not significant

Table 8 Correlations using household-level, built-form variables against travel behaviour

Neighbourhood-Level Built-Form Variables	Household-Level Travel Behaviour Variables						Neighbourhood-Level Behaviour Variables		
	Walk or Bike to N'hood Destin-ations	Walk or Bike in the N'hood With no Destination	Walk More Now than Before	Drive Less Now than Before	Number of Walking Trips	VKTs	Avg. VKTs per H'hold	% of H'holds Reporting Walking Trips	Avg. Walking Mode Share
Sidewalks	+	+	+	+	+	NS	-	+	+
Smaller setbacks	+	NS	+	+	NS	NS	-	+	-
Street width	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pedestrian connectivity	+	NS	+	NS	NS	+	+	NS	+
Design satisfaction	+	+	+	+	NS	NS	-	+	+
Safe for walking or cycling	+	+	+	+	+	NS	-	+	+
Convenient access to public open space	+	+	+	+	NS	NS	-	+	+

+ = positive correlation significant at the 95% confidence level
- = negative correlation significant at the 95% confidence level
NS = not significant

including whether the respondents were satisfied with the design of the neighbourhood; whether they found the neighbourhood safe for walking and cycling; and whether they had convenient walking or biking access to public open space. The travel behaviour variables are the same as those in the previous table.

The results from both tables generally confirm expectations derived from the literature. Although the correlations are not as expected in all cases, the picture that emerges from the statistical analysis is that the urban design features that are thought to increase active modes of transport and reduce car use are in fact linked with more walking and biking behaviour and less car use in our eight study neighbourhoods. Taken together, the results suggest that VKTs are more strongly correlated to larger-scale factors, such as neighbourhood dwelling density, employment within 5 km, housing mix and non-residential land uses within 1 km. On the other hand, walking and cycling activity is more strongly linked to smaller-scale factors, such as the presence of sidewalks, setbacks and occupant perceptions of neighbourhood walkability.

To control for interrelated factors, we conducted a multivariate regression analysis on household VKTs. In developing our regression model, we collapsed built-form variables into a smaller number of synthetic variables. Using this approach, we identified three factors as follows:

- **Factor 1:** high dwelling density and jobs within 5 km
- **Factor 2:** public open space and high walkability (includes pedestrian connectivity, sidewalks, setbacks and street widths)
- **Factor 3:** mixed land use and a dense street network

We then estimated regression models where we regressed the VKTs of individual households as a function of the following: neighbourhood built form (presented by the three synthetic variables); number of adults per household; automobile ownership; housing type; and household income. Additional independent variables included survey responses on neighbourhood design satisfaction, walk/bike safety, convenience and pleasantness. We have included only those households in the sample who reported at least 5 VKTs in a day. The assumption here is that households reporting fewer than 5 VKTs may be outliers.

Table 9 presents the results of the regression model. Relationships that are significant at the 95-per-cent confidence interval are highlighted in bold and italics under the significance column. The adjusted R-square for the model is 12.73 per cent, suggesting a modest fit. The model fit reported here is similar to that of other studies that relied on disaggregated data.

Table 9 Results of the regression model for VKT

Independent Variables	Estimate	Std. Error	t Value	Significance
Constant	11.60	10.64	1.09	0.28
Mixed land use and high street density	-3.84	1.01	-3.78	***0.00***
Public open space and high walkability	-6.81	1.08	-6.33	***0.00***
High res. density and employment in 5 km	-4.47	1.22	-3.65	***0.00***
Cars owned	4.05	1.61	2.52	***0.01***
Adults in household	5.49	1.10	4.98	***0.00***
Household income categories*:				
$35,001 to $50,000	1.21	11.04	0.11	0.91
$50,001 to $75,000	6.25	10.48	0.60	0.55
$75,001 to $100,000	13.76	10.33	1.33	0.18**
$100,001 to $150,000	15.61	10.28	1.52	0.13**
Over $150,000	13.56	10.36	1.31	0.19**
Perception variables:				
N'hood very safe for walking	0.00	2.17	0.00	1.00
Very satisfied with urban design	0.94	2.32	0.41	0.68
N'hood very convenient for walking	-1.04	2.48	-0.42	0.68
N'hood very pleasant for walking	-0.78	2.65	-0.30	0.77
Single-detached housing unit	0.44	2.56	0.17	0.86
Adjusted R-square	12.73%			

* Base income category is less than $35,000
** When using a one-tail hypothesis, significance levels are all under 0.1 (90% confidence level)

To summarize, the regression model suggests that new urbanist design characteristics are associated with reduced VKTs, even when controlling for income, housing type, household size and automobile ownership. As expected, the model also indicates that VKTs rise with an increase in the number of cars owned, number of adults in the household and household income. For example, households with annual incomes over $75,000 drive from 13.5 to 15.6 more VKTs daily than those with incomes under $35,000. When we tested for the assumption that these higher income households would report higher VKTs than those earning under $35,000 (using only the upper tail of the distribution), the results show statistically significant coefficients at the 90-per-cent confidence level or better. Finally, the model also implies that household perceptions about the neighbourhood built form do not have a significant impact on VKTs nor does housing type.

Influence of self-selection bias

While these findings are statistically robust, they can be questioned on the basis of the so-called "self-selection bias" argument. Like most empirical research that shows a link between neighbourhood form and travel behaviour, our findings could be explained by hypothesizing that households that prefer walking over driving were drawn to the neighbourhoods with new urbanist characteristics and this is why we find less driving and more walking in the NUDs compared with the CSDs in our sample. This interpretation challenges the conclusion that urban form affects travel behaviour because it implies that the physical characteristics of the neighbourhood are not directly responsible for differences in walking and driving behaviour; it is the household preference for driving or walking that produces the observed differences.

In order to eliminate this as a possible explanation for our results, we developed a "walk predisposition" variable and added it as an explanatory variable in the regression analysis to see if it was a significant predictor of travel behaviour. The predisposition variable was based on the neighbourhood type choices of each household in our sample. Since we asked respondents about the location of their previous residence (before moving to their current residence in one of the eight neighbourhoods in our study), we could collect information about the neighbourhood surrounding the household's previous location. These "previous location" neighbourhoods were classified on a scale of 1 to 5 based on their walkability characteristics (including density, street density, number of jobs within 5 km, distance to Central Business District, mode split, and average travel distance to work).

Table 10 Results of the regression model for VKT

Independent Variables	Estimate	Std. Error	t Value	Significance
Constant	17.00	11.77	1.44	0.15
Mixed land use and high street density	-3.24	1.08	-3	0.00
Public open space and high walkability	-7.27	1.13	-6.44	0.00
High res. density and employment in 5 km	-3.92	1.44	-2.72	0.01
Cars owned	3.97	1.68	2.37	0.02
Adults in household	5.04	1.17	4.32	0.00
Household income categories*:				
$35,001 to $50,000	-1.59	12.17	-0.13	0.90
$50,001 to $75,000	2.85	11.62	0.25	0.81
$75,001 to $100,000	11.00	11.45	0.96	0.34
$100,001 to $150,000	11.89	11.35	1.05	0.30
Over $150,000				
Perception variables:	-0.08	2.28	-0.04	0.97
N'hood very safe for walking	1.61	2.44	0.66	0.51
Very satisfied with urban design	-1.77	2.63	-0.67	0.50
N'hood very convenient for walking	-1.49	2.80	-0.53	0.60
N'hood very pleasant for walking	0.60	2.65	0.23	0.82
Walk predisposition				
Households with medium walk predisposition	-7.61	4.293793	-1.77	0.077
Household with high walk predisposition	0.02	7.476533	0	0.998
Observations	1037			
Adjusted R-square	12.26%			

The eight "current location" neighbourhoods in our sample were also classified using the same definitions. Households that moved from one highly walkable to another highly walkable neighbourhood were deemed to have a "high walk predisposition" whereas those who moved from a mid-walkable to a highly walkable or from a highly walkable to a mid-walkable neighbourhood were given a "medium walk predisposition" score. All other households were given a "low walk predisposition" score.

The "walk predisposition" score did not return a statistically significant coefficient in the regression model (see table 10) suggesting that walk predisposition does not help explain the difference in VKTs among households and that the self-selection bias can be dismissed as an explanation for why we observed less driving in the NUDs compared with the CSDs in our sample. Thus, our finding remains that the built-form variables of the neighbourhoods in our sample are significant influencers of travel behaviour.

RESPONSES TO THE RESEARCH QUESTIONS

This study poses the question as to whether the NUDs achieved certain built-form design objectives and showed specific behavioural and attitudinal differences compared to those found in the CSDs. We are now in a position to address these questions in the context of the eight neighbourhoods surveyed in this study.

Design characteristics

Closer access to daily destinations: The four NUDs, on average, had 80 per cent more daily destinations, such as stores and schools, within 1 km of the neighbourhood centroid than did CSDs. They also had slightly more public open space as a percentage of the total site area than did the CSDs. While the NUDs had fewer jobs within 5 km than did the CSDs, this is related to the fact that each neighbourhood pair was selected to have a similar location and distance to the metropolitan core.

More pedestrian routes and connectivity: As measured by the ratio of straight line to pedestrian network distances, we found that the NUDs had a 5-per-cent higher pedestrian connectivity index than their CSD counterparts. Together, the path, street and lane density was about 36 per cent higher in the NUDs, on average, than in the CSDs. The NUDs had nearly three times the percentage of streets with sidewalks on both sides than the CSDs.

More housing choice: Generally, the NUDs had lower percentages of detached and semi-detached homes than the comparable CSDs (35 per cent, versus 76 per cent) and higher percentages of row houses and multi-family housing forms (65 per cent, versus 24 per cent). The NUDs offered a much richer mix of housing types than found in the CSDs.

Less land per housing unit: Housing densities in NUDs were 74 per cent greater, on average, than in CSDs, with NUDs having about 20.2 uph, against 11.6 uph in the CSD neighbourhoods. NUDs also had smaller setbacks and narrower streets than their CSD counterparts.

Behaviour and attitudes

Less car use for weekday urban travel: The mode split analysis suggests that NUD respondents had a lower auto mode share (as a driver or passenger) than their CSD counterparts (78 per cent, versus 85 per cent). The analysis of the 24-hour VKTs reported by each responding household suggests that the CSDs had 24 per cent higher VKTs per household than their NUD counterparts (46.0 km, versus 37.1 km). Moreover, respondents moving to NUDs were more likely to report a decrease in driving compared to their previous location, while respondents in CSDs were more likely to report an increase in car ownership and more driving in their new location.

More walking and bike use for daily destinations: We found significant evidence to support the assumption that responding households in the NUDs walk and bike more than their CSD counterparts. In fact, 52 per cent more NUD households reported walking trips than did their CSD counterparts (21.3 per cent, versus 14 per cent). Fully 51 per cent of NUD households reported walking and biking to local services and stores several times a week, compared to only 19 per cent for CSD households. Also, 64 per cent of NUD respondents said they stroll or bike for leisure several times a week in the warm months, compared to 52 per cent in the CSDs. Moreover, respondents from the NUDs were almost twice as likely as respondents from the CSDs to

report that they were walking a lot more in their current location than in their previous home (37 per cent, versus 20 per cent).

Greater use of public transit: The modal share of public transit was low in both types of developments, with, on average, no difference between the two (9-per-cent modal share). Although the NUDs had more transit-supportive densities, the levels of transit service to NUDs and their counterpart CSDs were similar, as were each pair's locations relative to the metropolitan core.

Higher resident satisfaction with neighbourhood design: The survey revealed that, in comparison with their CSD counterparts, nearly double (60 per cent, versus 34 per cent) the respondents in the NUDs reported being very satisfied with the physical design of the streets, landscaping and façades in their neighbourhoods. Similarly, double the respondents in the NUDs found the streetscapes very pleasant for walking, compared to the CSD households (85 per cent, versus 44 per cent). Likewise, the design of the streetscape was considered to be very safe for walking and biking by 51 per cent more NUD respondents than households residing in the CSDs (55 per cent, versus 37 per cent).

More use of public open/green space: A proportion of 52 per cent of NUD respondents reported visiting public open spaces several times a week, compared to only 40 per cent of the respondents in CSDs, even though our neighbourhood metrics showed that NUDs had only slightly more public open space than CSDs. Households in NUDs were much more likely to report that they found it very convenient to either walk or bike to parks than households in comparable CSDs (70 per cent, versus 47 per cent).

More interaction with neighbours: Most of our indicators suggest that NUD respondents had more interaction with their neighbours than did their CSD counterparts. They greeted their neighbours more often than did the respondents living in the CSDs, with 35 per cent reporting a greeting almost every time they were out for a walk, compared to 27 per cent for CSD households. NUD households also reported socializing face-to-face with their neighbours more often, with 40 per cent saying they did so several times a week, in contrast to CSD households, 34 per cent of whom reported doing so. Although CSD respondents were more likely to hold a membership in sports or social groups, households in NUDs attended more community events per year, on average, than their CSD counterparts.

Greater sense of neighbourhood attachment: Not surprisingly, given the higher degree of satisfaction with the neighbourhood design and with stronger indicators of social interaction, the NUD respondents were found to be more attached to their neighbourhoods than the CSD households (50 per cent, versus 36 per cent). This was the case, in spite of the fact the NUDs were more recently built and respondents had, on average, lived in them for fewer years than those living in the four CSDs.

CONCLUSIONS

Our overall conclusion is that there is considerable evidence that the four NUDs we studied achieved these objectives more successfully than their CSDs counterparts. The only exceptions were the modal share of transit (which was the same for both neighbourhood types) and jobs within 5 km. Both results reflect the fact that the CSDs were intentionally chosen to have similar levels of transit service and locations with respect to the metropolitan core as their NUD counterparts.

Our statistical analysis indicates that the built-form design features that are thought to increase active modes of transport and reduce car use are indeed linked with more walking and biking behaviour and less car use in our study neighbourhoods. VKTs are more strongly correlated to larger-scale factors, whereas walking and cycling activity is more strongly linked to smaller-scale factors. The regression model suggests that these design features are associated with reduced VKTs, even when controlling for income, housing type, household size and automobile ownership. As expected, the model also indicates that VKTs rise with an increase in the number of cars owned, number of adults in the household size and household income. Finally, the model also implies that household perceptions about the neighbourhood built form do not have a significant impact on VKTs nor does housing type.

We tested the self-selection bias as a possible explanation of these results and found that it is not a significant factor in explaining the differences in VKT in the presence of other explanatory variables.

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